$b\bar{b}$ cross section measurement at CDF

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Outline

- b production at the Tevatron
- The CDF detector
- The Silicon Vertex Trigger
- Jet reconstruction
- b-jet identification
- The $b\bar{b}$ di-jet cross section
- Comparison to Monte Carlo

b quark production

THE STUDY OF b PRODUCTION PROPERTIES IS AN IMPORTANT TEST TO pQCD

$$\frac{d\sigma\left(p\bar{p} \to BX\right)}{d\,p_T(B)} = \frac{d\sigma\left(q\bar{q}/gg/qg \to bX\right)}{d\,p_T(b)} \otimes F^{p\bar{p}} \otimes D^{b\to B}$$

Proton structure

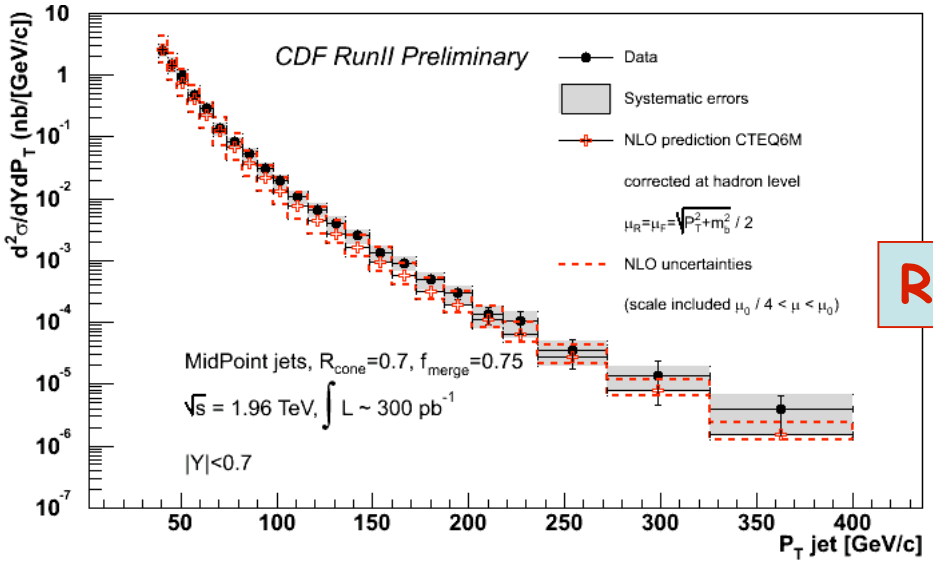
NLO QCD

Fragmentation

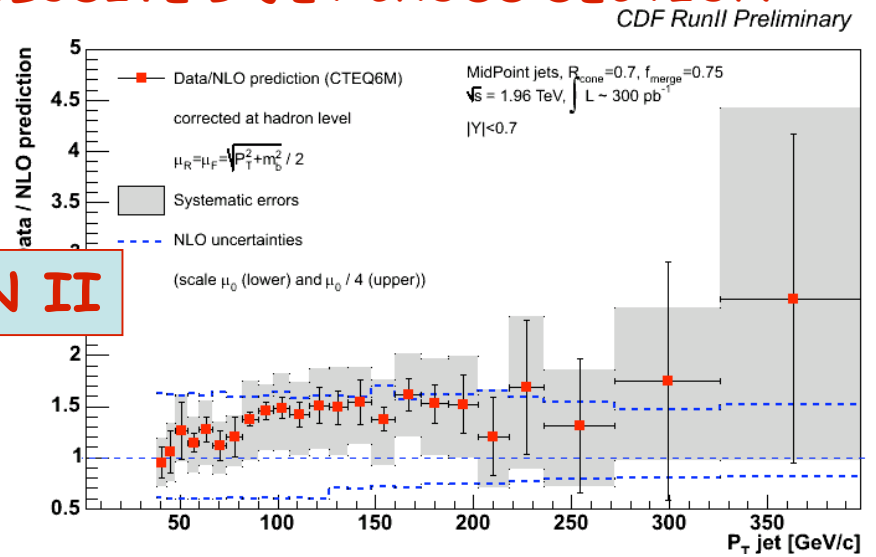
b-jets as experimental input:

- include most of quark fragmentation remnants
  small dependence on fragmentation
- wide P_T spectrum

CDF HAS ALREADY MEASURED THE INCLUSIVE B-JET CROSS SECTION



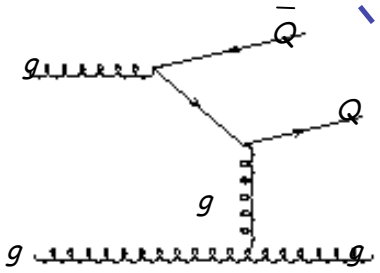
RUN II



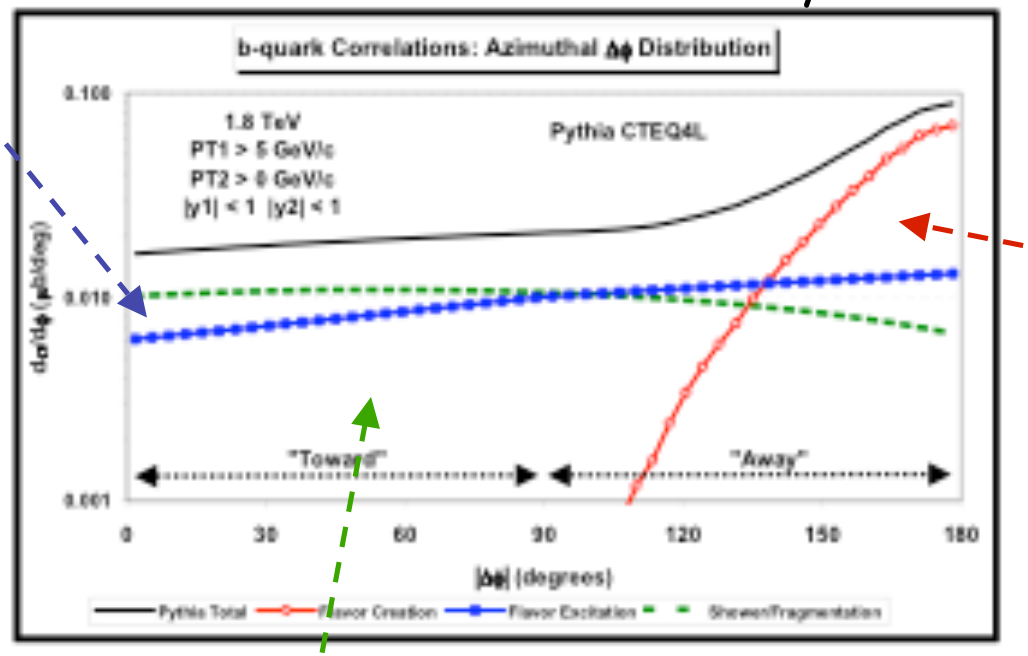
b quark production

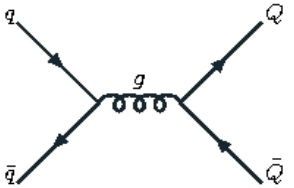
- $b\bar{b}$ CROSS SECTION AND CORRELATION GIVE A HINT ON b PRODUCTION MECHANISM
- GOOD TEST TO NLO VS LO PREDICTIONS

FLAVOUR EXCITATION

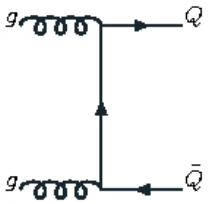


Run I LO Monte Carlo study

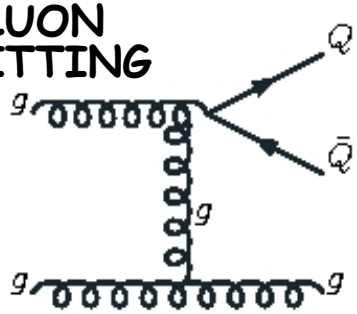




FLAVOUR CREATION



GLUON SPLITTING



SHOWERING

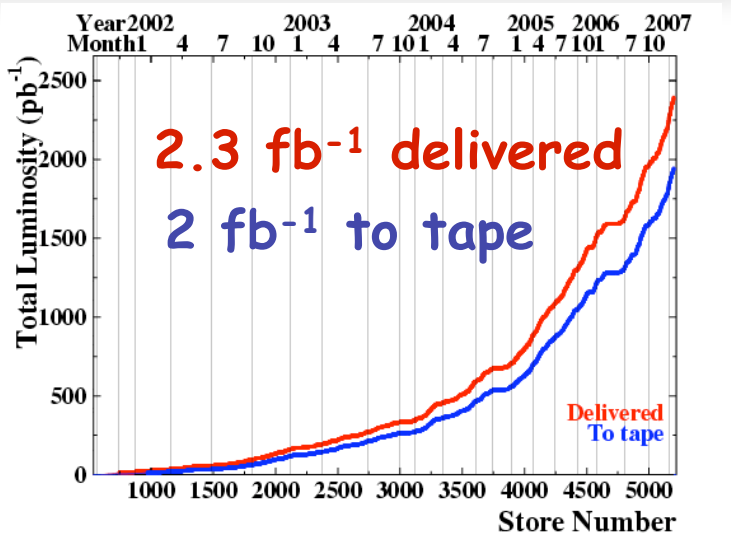
CDF

TEVATRON HAS DELIVERED MORE THAN 2 fb^{-1}

CDF FULLY UPGRADED FOR RUN II:

- SI & TRACKING
- EXTENDED CALORIMETERS RANGE
- L2 TRIGGER ON DISPLACED TRACKS
- HIGH RATE TRIGGER/DAQ

⇒ **~85 % DAQ EFFICIENCY**

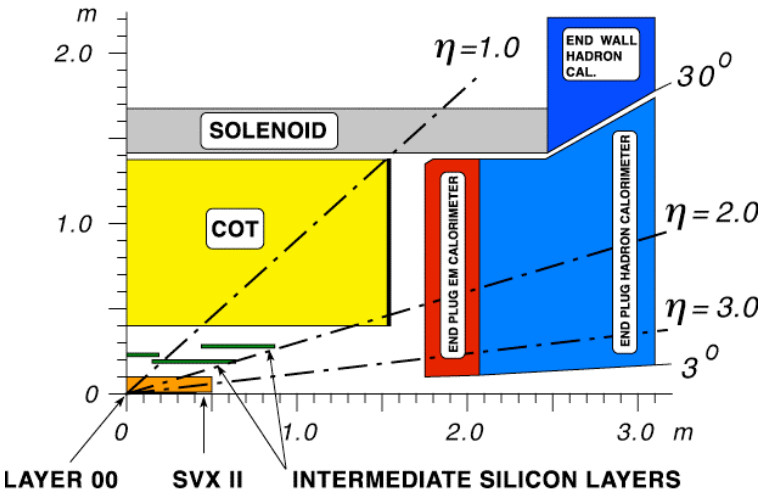


CALORIMETER

- CEM LEAD + SCINT $13.4\%/\sqrt{E_T} \oplus 2\%$
- CHA STEEL + SCINT $75\%/\sqrt{E_T} \oplus 3\%$

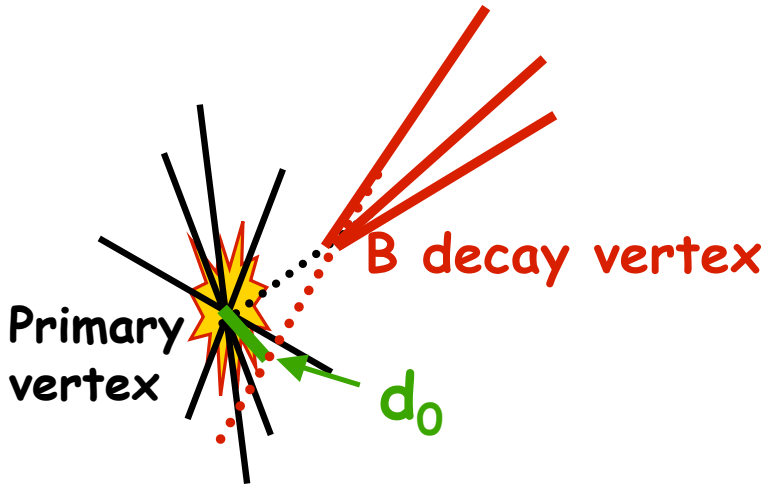
TRACKING

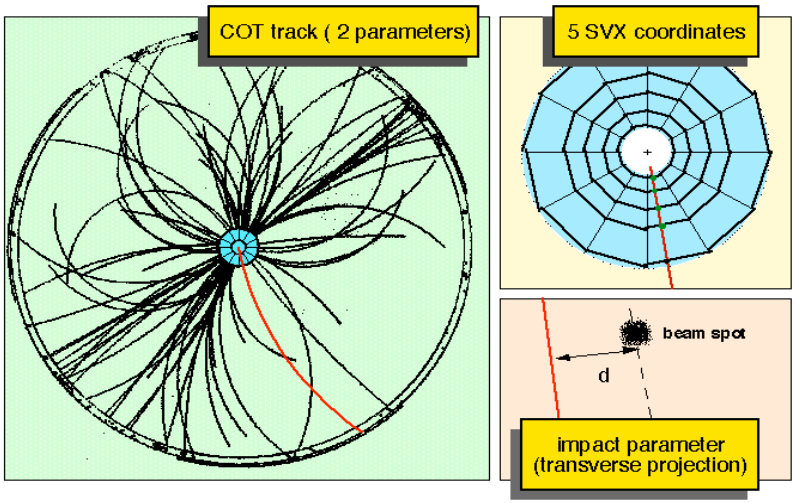
- $\sigma(d_0) = 40\mu m$ (INCL. $30\mu m$ BEAM)
- $\sigma(P_T)/P_T = 0.15\ \% P_T$



Silicon Vertex Trigger

σ(bb) ~ 50 μb @ 1.96 TeV -> RATE OF FEW KHz

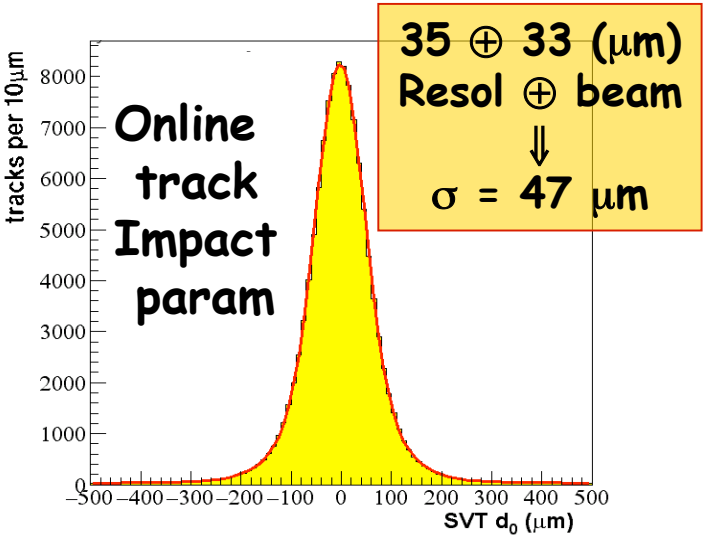




LONG LIFETIME (~1.5 ps) OF B-HADRON

-> DEDICATED IMPACT PARAMETER TRIGGER BASED ON SILICON DETECTOR HITS AND L1 FAST TRACKER INFO

USE @ HIGH PT:
SEARCH FOR NEW PHYSICS
NEW FOR QCD STUDIES

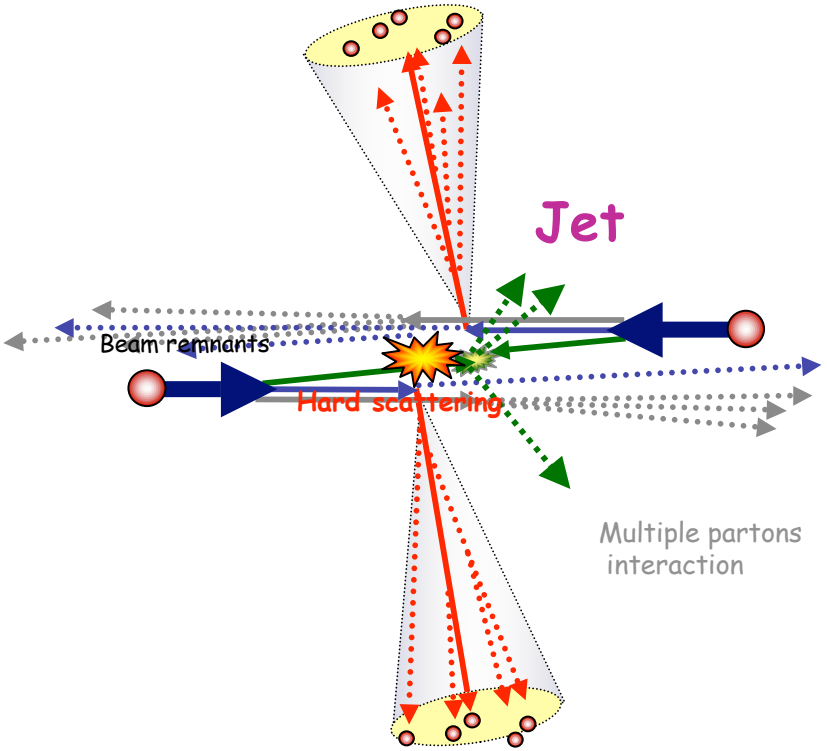


Jet reconstruction

Final state partons result in collimated flows of hadrons: jets

CONE ALGORITHM: PARTICLES OR TOWERS CLUSTER WITHIN A (η,ϕ) CONE

- **Seed towers**: Only iterate over towers above $E_T > 1$ GeV



Need to correct jet energy:

Detector effects:

- resolution and efficiency
- pile-up interactions (up to ~4)

Model dependent:

- fragmentation/hadronization effects
- mc based -> to be tuned on data

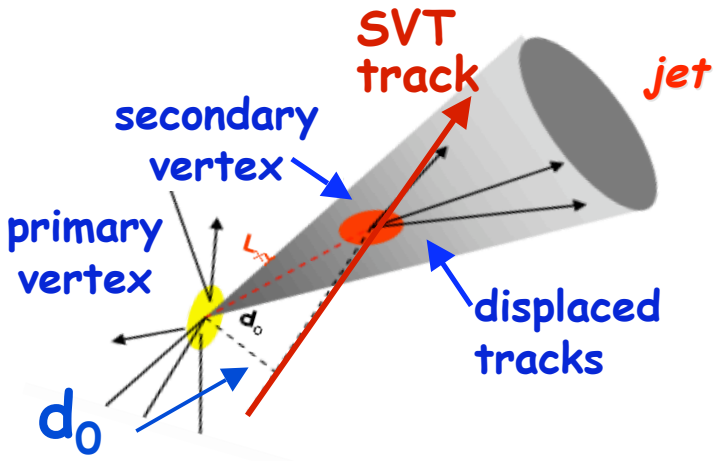
Underlying event

In this measurement: specific b-jet correction

Identifying b-jets

B-TAGGING:

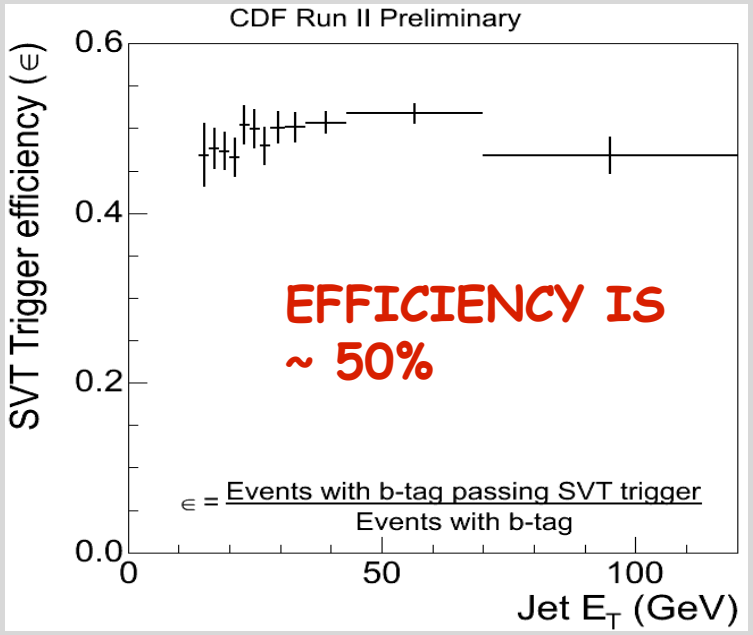
SEARCHING FOR THE B DECAY VERTEX



- Need ≥ two displaced tracks to reconstruct a secondary vertex

- Require secondary vertex to be well separated from primary vertex in r-ϕ space by cutting on L_{xy} significance

SVT TRIGGER EFF. FOR B-TAGGED JETS



MEASURED ON DATA

Event selection

ONLINE SELECTION:

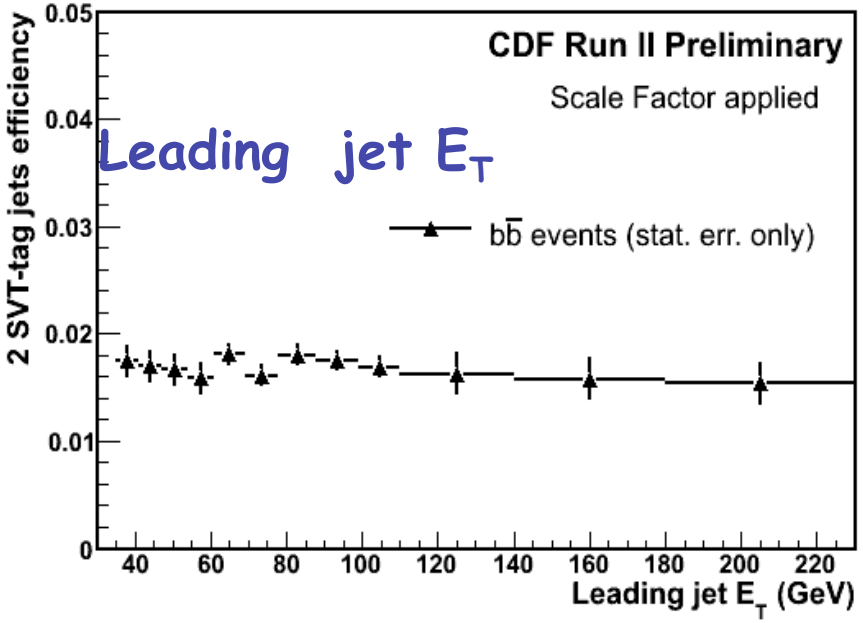
- **Level1**: 2 L1 TRACKS AND 2 CAL TOWER
- **Level2**: **2 SVT TRACKS $|d_0|>100$ μm**
  AND 2 CAL CLUSTER $E_T>15$ GeV
  ($\Delta\phi$ CLUSTER-TRACK MATCHING)
- **Level3**: 2 TRACKS **MATCHED** TO 2 JETS

NEED A TIGHT OFFLINE SELECTION TO ACCOUNT FOR EVENT SHAPING BY THE TRIGGER

OFFLINE SELECTION:

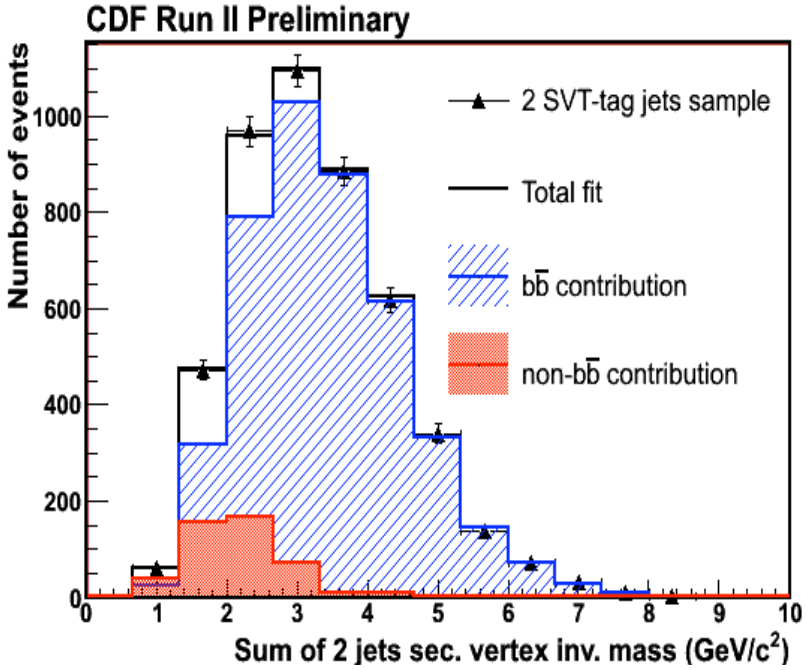
- **PRIMARY VERTEX $|Z|<60$ cm** FOR GOOD ENERGY MEASUREMENT AND VERTEXING
- **2 SVT TRACKS** $|d_0|>120$ μm
- 2 **b-TAGGED JET** (CONE 0.4)
  $E_T>35$, 32 GEV, $|\eta|<1.2$
- **GEOMETRICAL (ΔR)**
  TRACK - JET MATCHING

OFFLINE SELECTION EFFICIENCY IS MEASURED IN MC & SCALED TO DATA



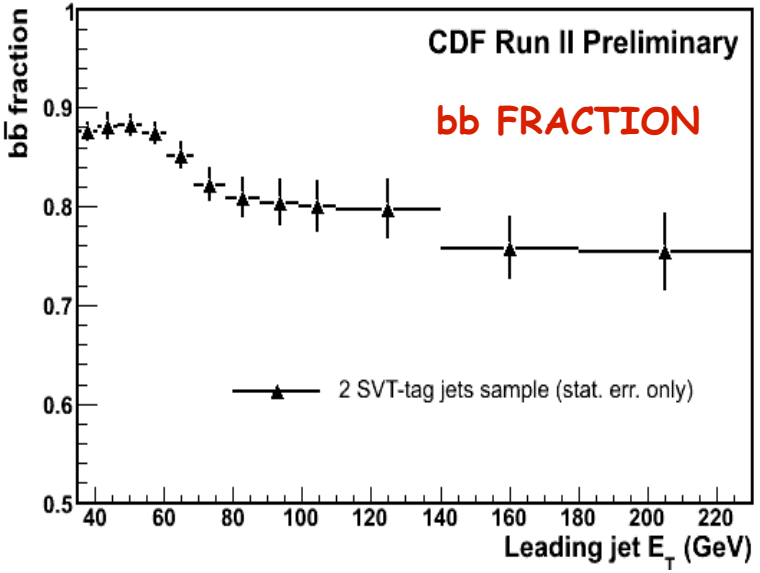
b purity of tagged jets

b JET FRACTION IN A TAGGED JET SAMPLE CAN BE EXTRACTED FROM DATA:
the **invariant mass** of the tracks **of the secondary vertex** is different for b/c/light or gluon jets



In a 2 tagged jet sample:

- **SUM SEC. VTX MASS OF 2 JETS**
- **BUILD bb AND NON-bb TEMPLATES**
- **FIT DATA**



SVT + TAG selection has low efficiency
BUT very high purity ~80%

$b\bar{b}$ di-jet cross section

$$\frac{d\sigma}{dE_T \Delta\eta} = \frac{N_{2SVT} \cdot f^{2b}_{2SVT} \cdot C_i}{\Delta\eta \cdot \Delta E_T \cdot \varepsilon_{2SVT} \cdot \int \mathcal{L}}$$

N_{2svt}: Number of events including 2 SVT-tagged jets

f^{2b}_{2svt}: bb-jets fraction

ε_{2svt}: Efficiency for 2 SVT-tagged jets
- Leading jet: E_T^{corr}>35 $|\eta|$<1.2
- Second jet: E_T^{corr}>32 $|\eta|$<1.2

C_i: Correction factors from Monte Carlo for acceptance and smearing effects

$\Delta\eta$: Pseudorapidity range $|\eta|$<1.2

ΔE_T: Transverse energy bin size

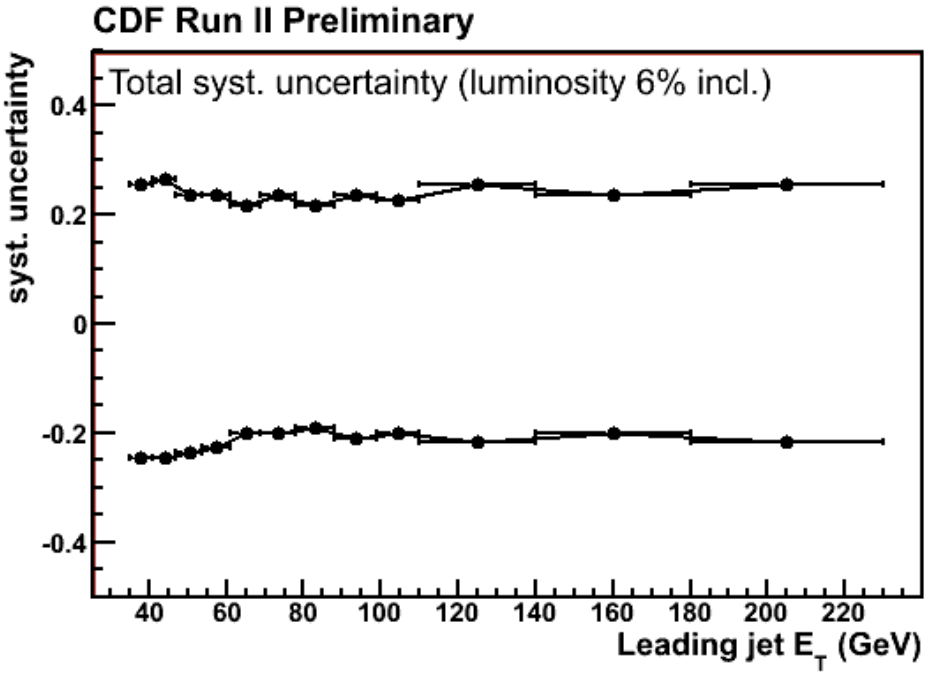
$\int \mathcal{L}$: Integrated luminosity

E_t^{corr}: **specific correction** is applied to account for harder fragmentation and b-hadron decays inside the jet

Syst. uncertainties

TOTAL SYSTEMATIC UNCERTAINTIES ARE ~20-30 %

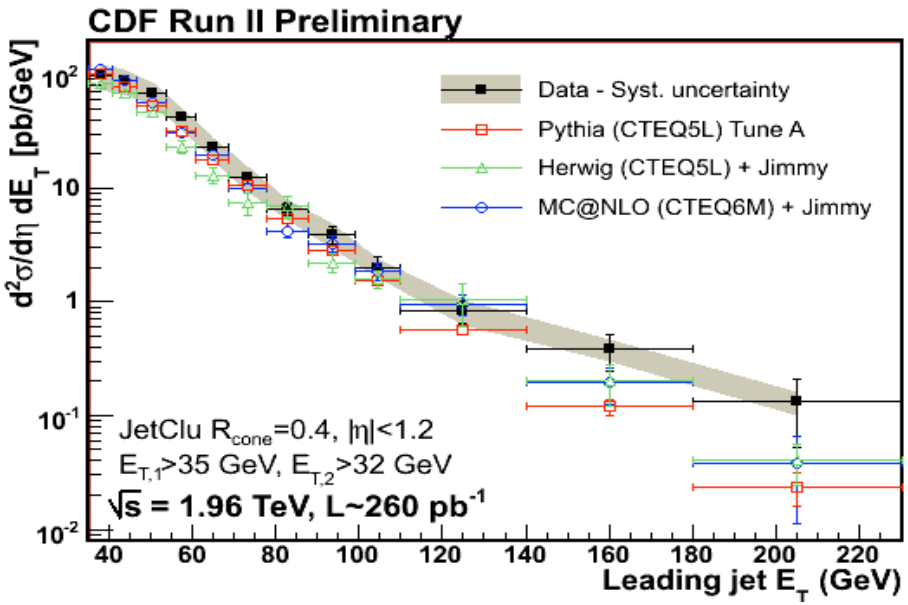
- JET ENERGY SCALE (15%-20%),
- LUMINOSITY (6%)
- UNFOLDING FACTORS (4%)
  - E_T DEPENDENCE DATA/MC
- TAGGING EFFICIENCY (4%)
  - b QUARK MULTIPLICITY INSIDE THE JET
- B-PURITY (~7%) (fraction fit)
  - COMPOSITION OF NON-b TEMPLATES (b/c/LIGHT RATIOS)
  - SECONDARY VERTEX MASS RECO (TRACKING EFFICIENCY IN DATA AND MC)

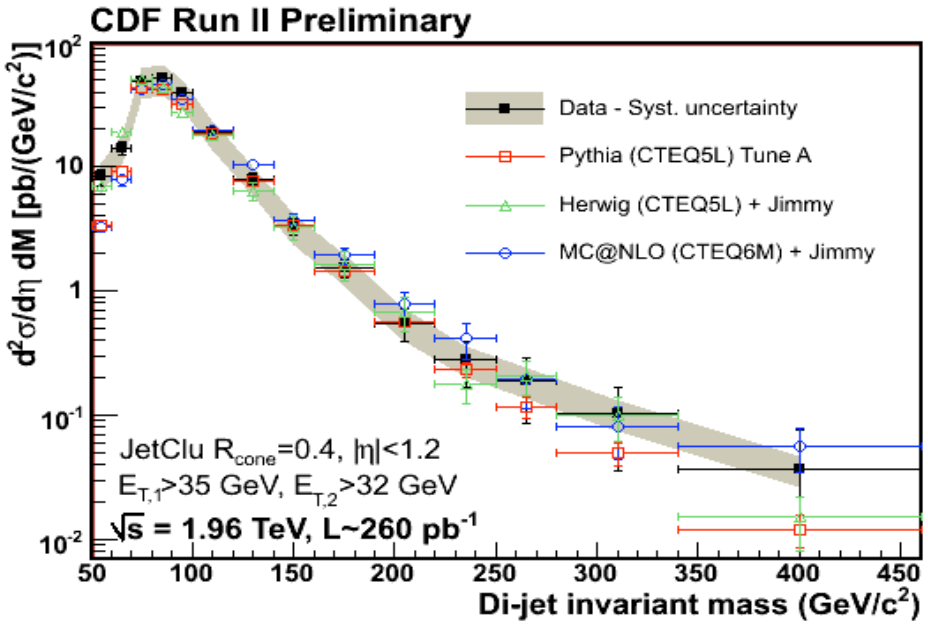


$b\bar{b}$ di-jet cross section

Data is compared to Monte Carlo prediction:

- PYTHIA (TUNE A)*
- HERWIG + JIMMY °
- NLO MC@NLO + JIMMY

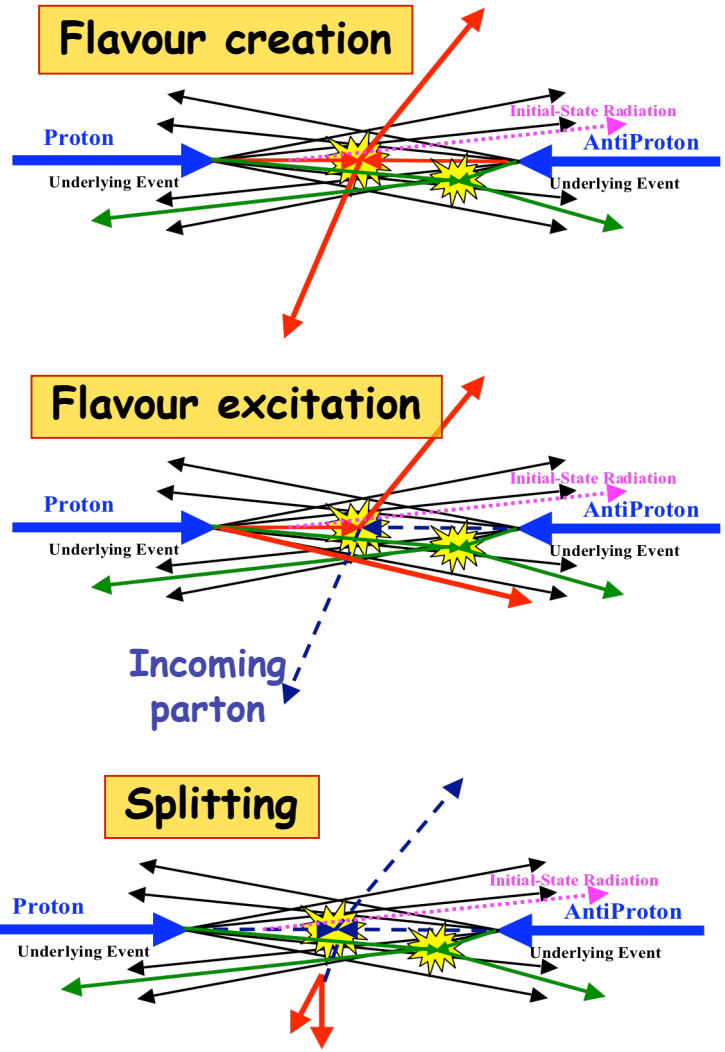




* tuned on Run I data for underlying event (UE)

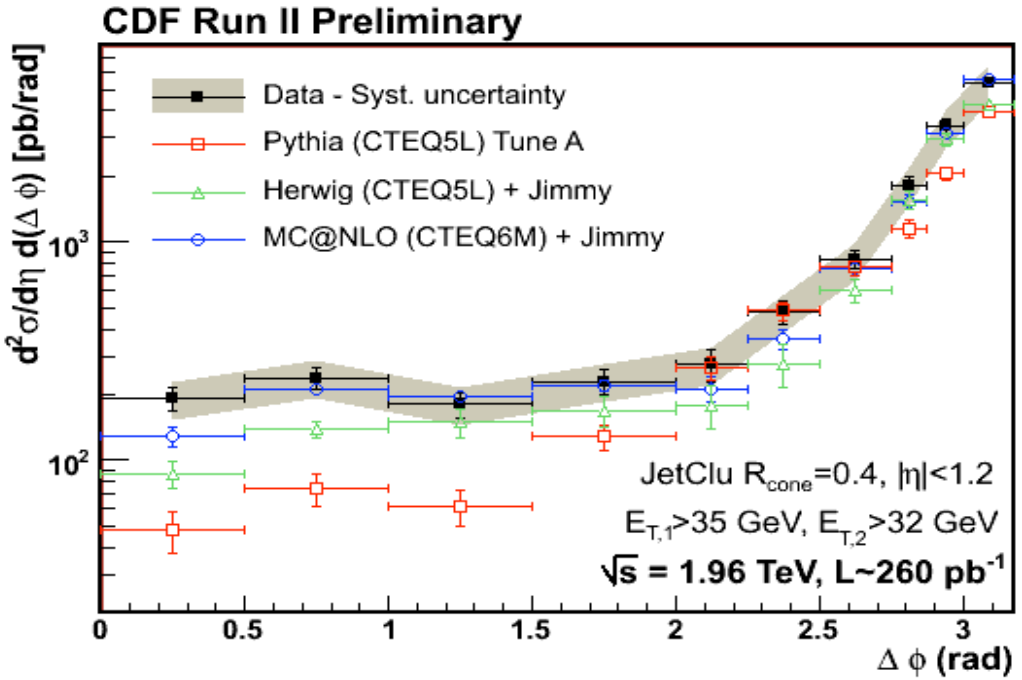
° Multi-parton interactions generator links to Herwig (see hep-ph/9601371)

Δφ correlation



Δφ CORRELATION IS SENSITIVE TO PRODUCTION MECHANISMS

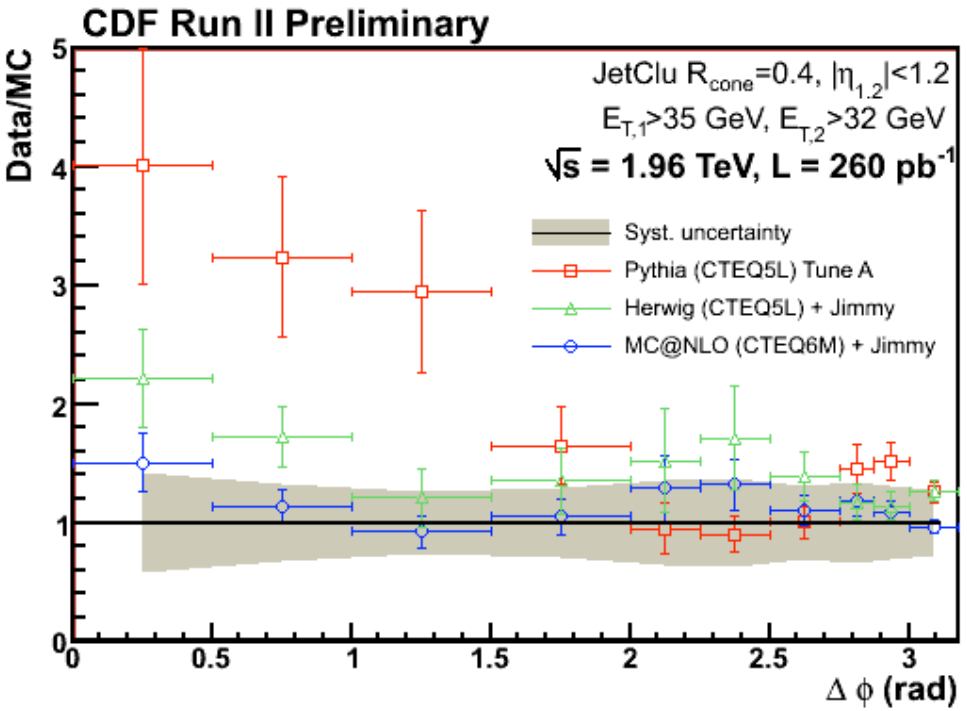
- PEAK @ LARGE Δφ
- NON NEGLIGIBLE TAIL AT LOW Δφ



Δφ correlation

MC@NLO agrees with data within the systematic error **AND describes low Δφ better than Herwig + Jimmy**

Herwig + Jimmy prediction is better than Pythia.

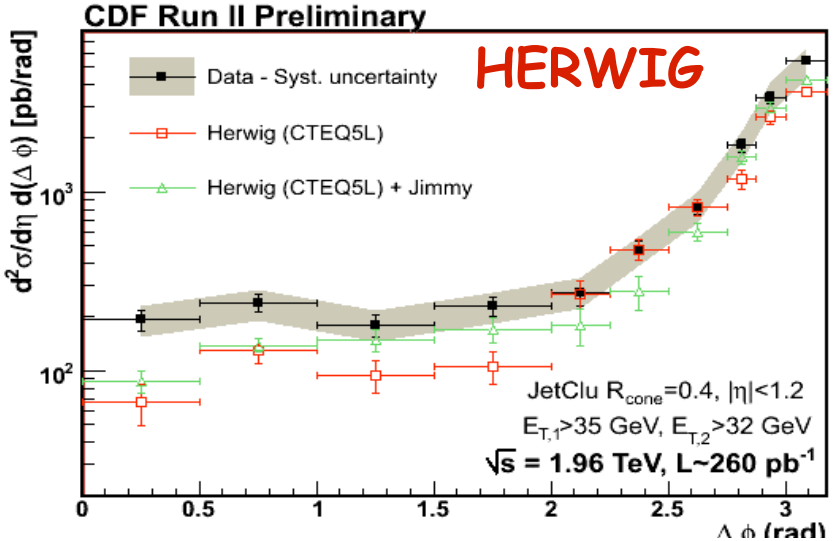


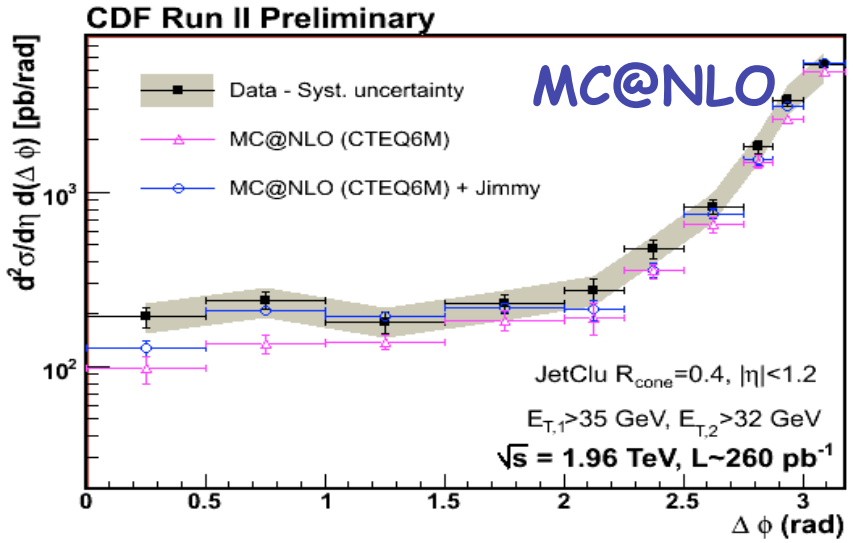
-> In the region E_T(jet1)>35 GeV, E_T(jet2)>32 GeV $|\eta_{1,2}|$<1.2

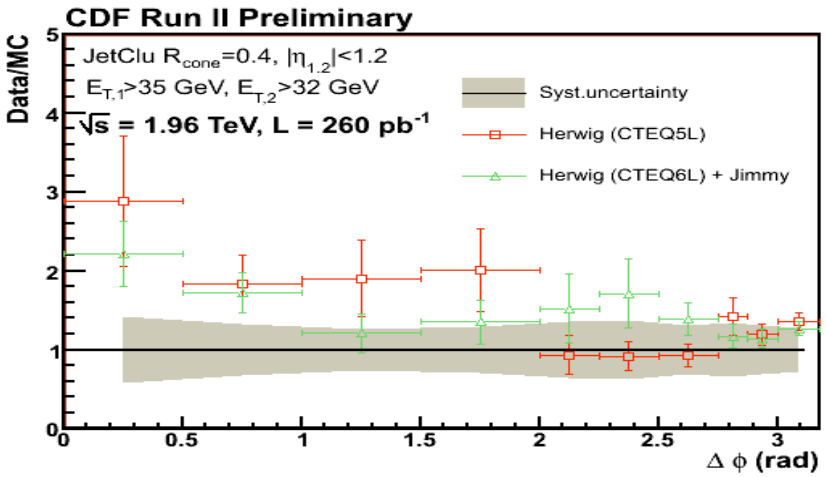
LOW Δφ prediction is different at LO and NLO (MC@NLO)

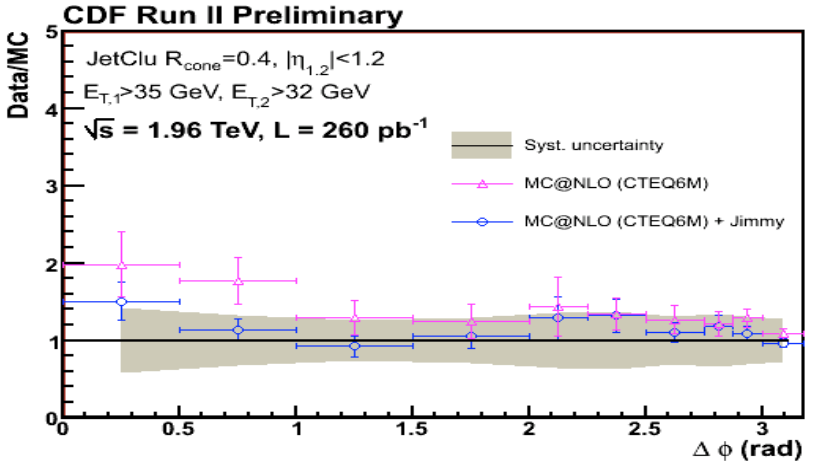
Δφ correlation

Both LO and NLO predictions are enhanced by adding Multi- Parton interaction simulation (Jimmy):









Summary

A PRELIMINARY MEASUREMENT OF THE $b\bar{b}$ DI-JET CROSS SECTION AND ANGULAR CORRELATION HAS BEEN PRESENTED

- THE SVT TRIGGER IS VERY HELPFUL IN THE STUDY OF HIGH PT QCD PROCESSES AND WELL UNDER CONTROL
- COMPARISON TO NLO IS GOOD
  - $b\bar{b}$ ANGULAR CORRELATION SHOWS EVENTS ARE MAINLY PRODUCED BY **FLAVOUR CREATION** MECHANISMS

  BUT

  LOW $\Delta\phi$ TAIL SUGGESTS NON- NEGLIGIBLE CONTRIBUTION FROM **OTHER PROCESSES**
- THE SIMULATION OF THE UNDERLYING EVENT IS NECESSARY TO CORRECTLY DESCRIBE DATA

Bkup

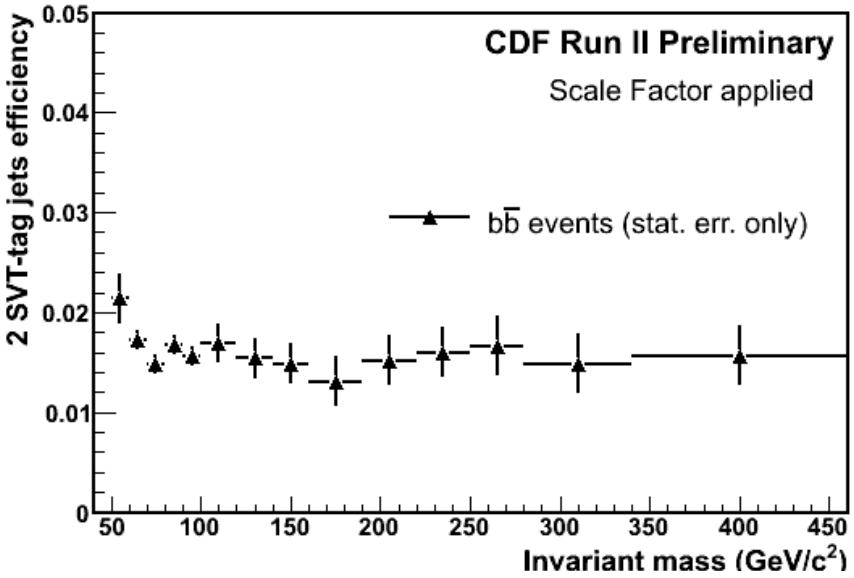
Trigger selection

- **Level 1**
  - Two 5GeV towers
  - Two XFT tracks pt>2GeV/c
- **Level 2**
  - Two clusters (Et>15 GeV, $|\eta|<1.5$)
  - Two SVT tracks |d0|>100μm
  - Cluster-SVT matching ($|\Delta\phi|<0.7$)
- **Level 3**
  - Two cone-04 jets Et>20 GeV
  - Two COT tracks matched to SVT (|d0|>100 μm)
  - Two Si tracks matched to SVT (|d0|>80 μm)

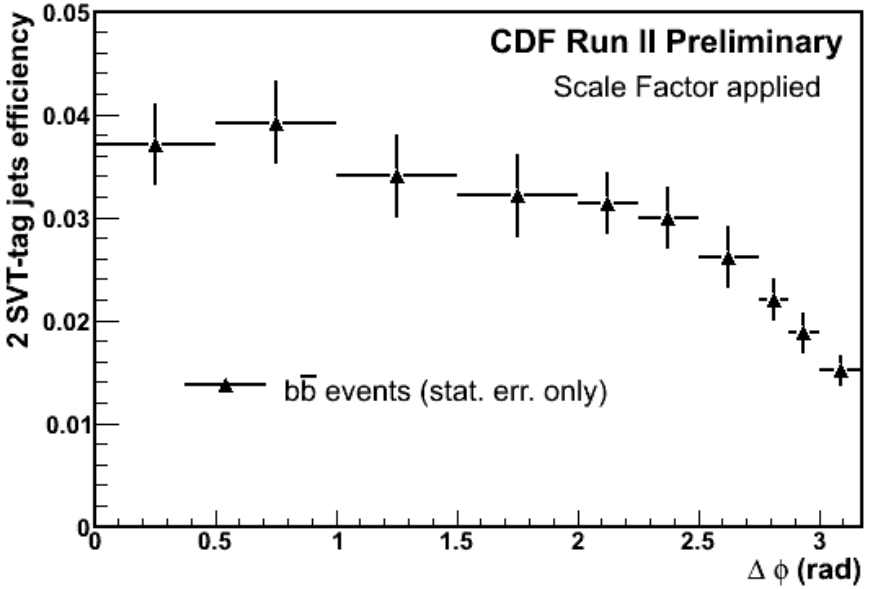
Bkup

SVT-tag efficiency

DI-JET INVARIANT MASS



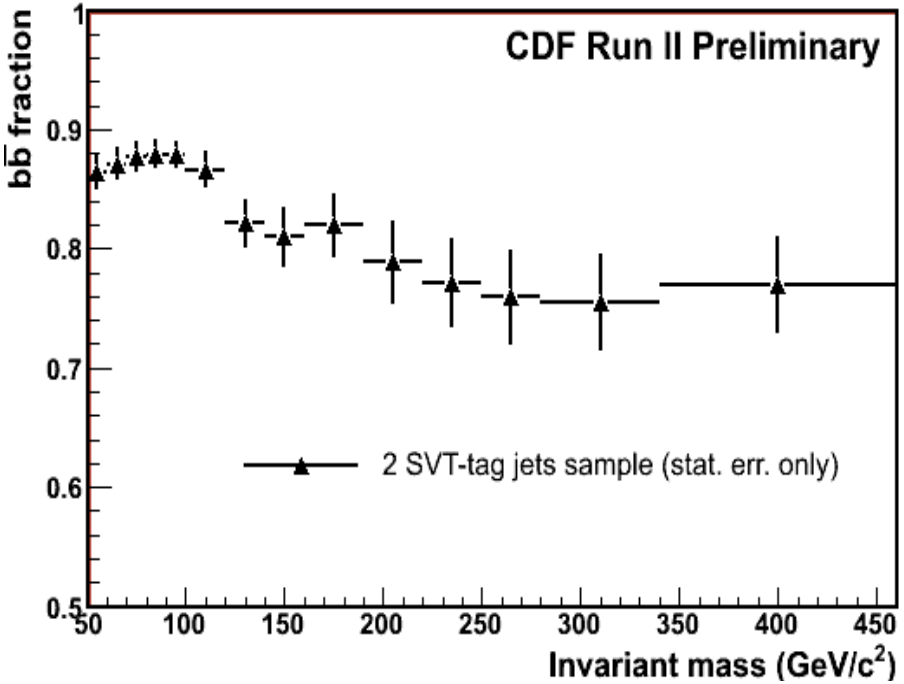
DI-JET $\Delta\phi$



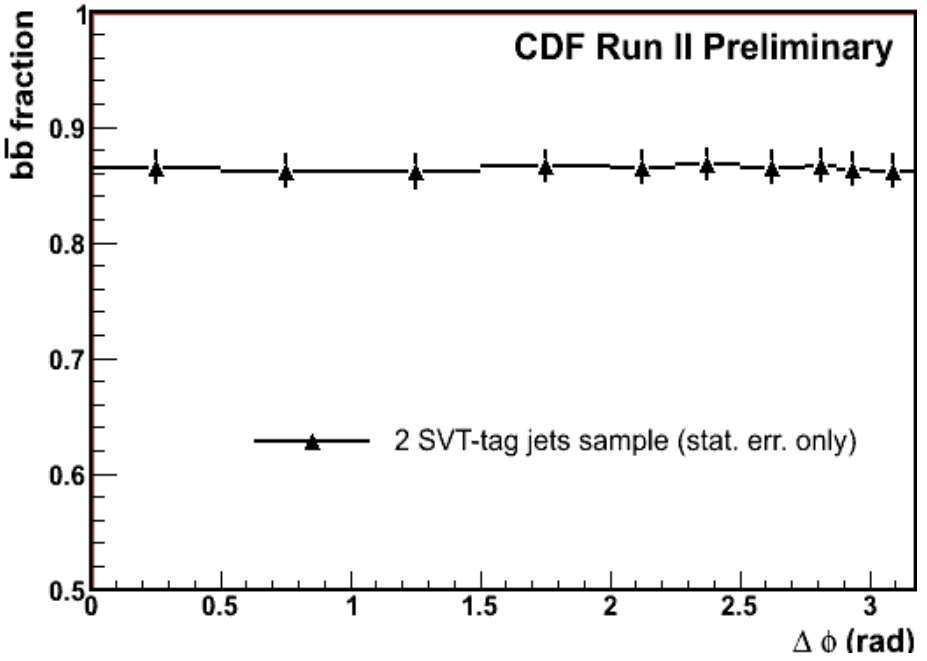
Bkup

bb purity

DI-JET INVARIANT MASS

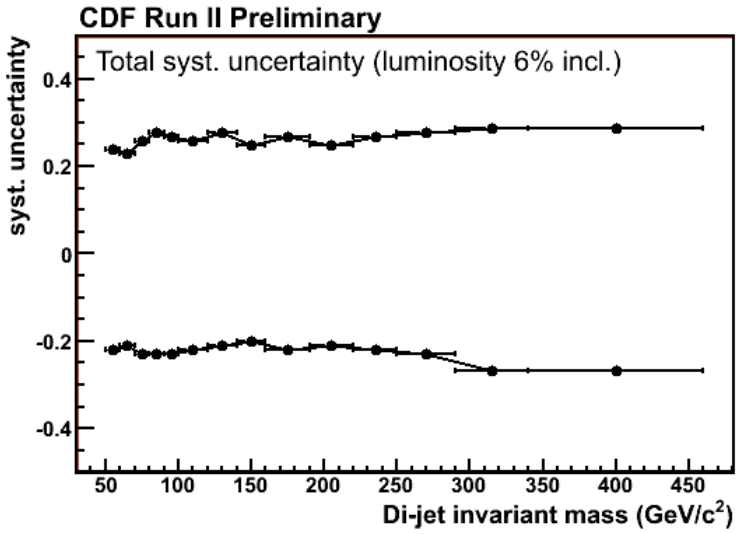


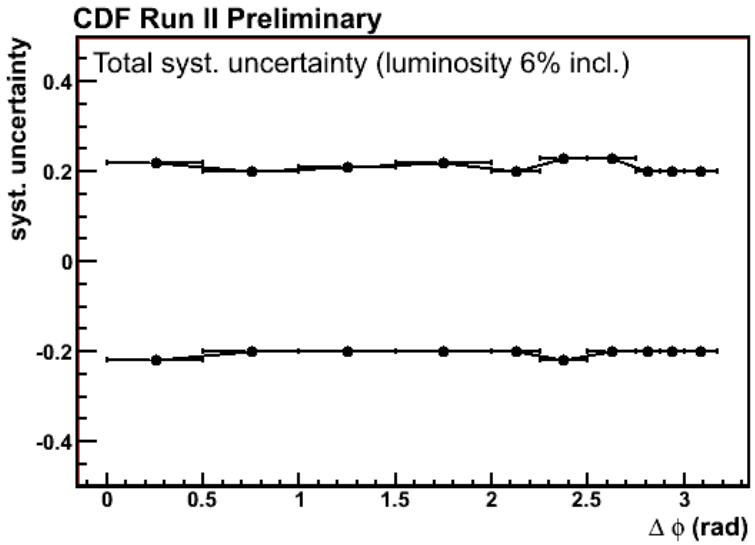
DI-JET $\Delta\phi$



Bkup

Systematic uncertainties:





Bkup

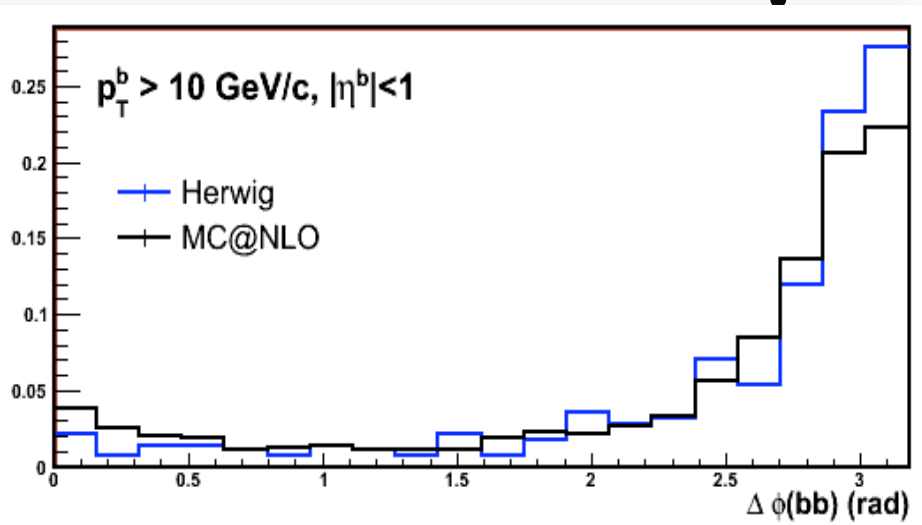
MC@NLO vs LO

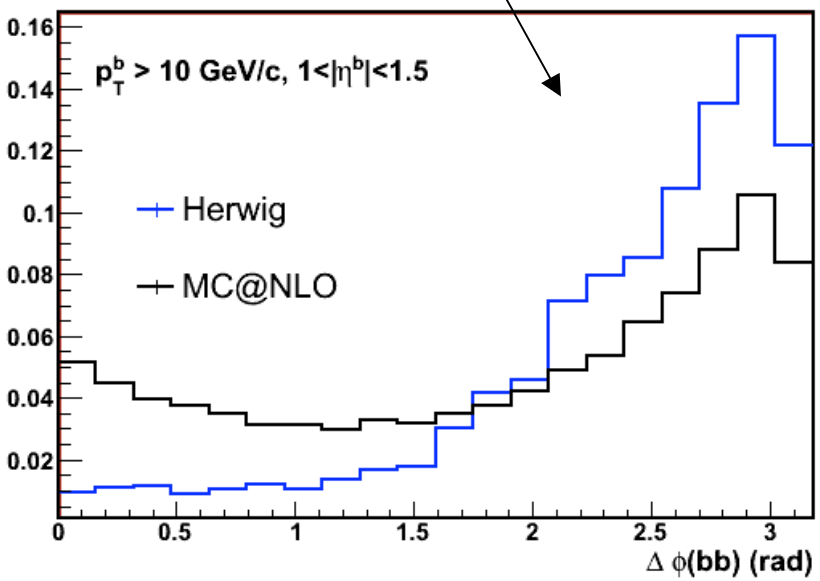
Select events with 2 b quarks: p_T^b >10GeV and

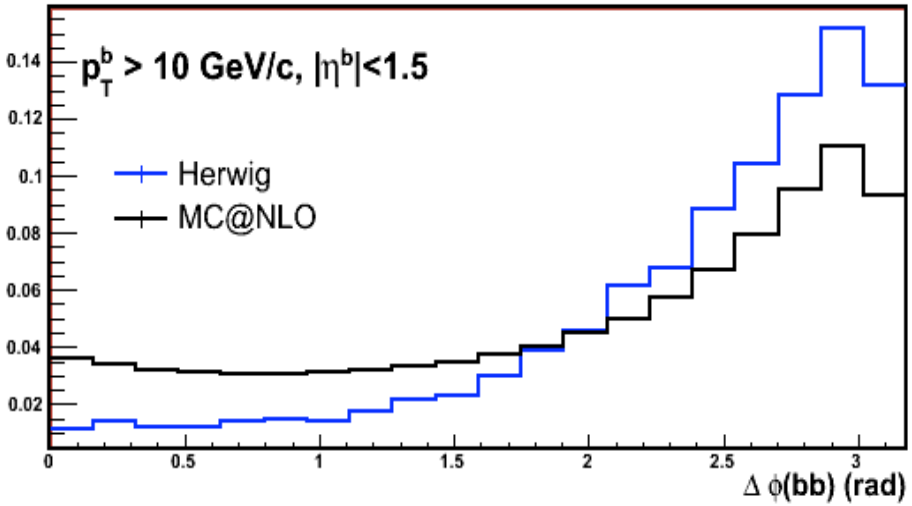
$|\eta|<1$

$|\eta|<1.5$

$1<|\eta|<1.5$







ONLY COMPARE SHAPES
NORMALIZATION TO SAME AREA